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Performance and stability of different tomato (*Solanum lycopersicum*) genotypes

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Tomato (*Solanum lycopersicum* Mill.) is one of the most important vegetable crops grown widely all over the world. It is a self-pollinated crop and is a member of *Solanaceous* family with 2n = 24 (Rick 1969). Peru Equador region is considered to be the centre of origin. The estimated world production of tomato is about 125.02 million tonnes and the total area under its cultivation is about 45.5 lakh ha. Indian contribution to the world's production was 10.26 million tonnes of annual production with an area of 5.72 lakh ha in 2006. In Karnataka, tomato occupies an area of 0.47 lakh ha with an annual production of 12.85 lakh tonnes (NHB 2007). Tomato universally treated as 'Protective Food', is being extensively grown as annual plant. It is a rich source of minerals, vitamins, and organic acids (healthy acid). Among the main fruits and vegetables, tomato ranks 16th as source of vitamins. Tomatoes are important source of lycopene, minerals, Vitamin-A, B and also excellent source of Vitamin-C.

Phenotypically stable genotypes are of great importance, because the environmental condition varies from year to year/ region to region. Wide adaption to the particular environment and consistent performance of recommended genotypes is one of the main objectives in breeding programme. Although a number of varieties have been recommended for the cultivation of tomato, the information on the stability is lacking for the agro-climatic conditions. Therefore, an experiment was undertaken considering necessity to evaluate and screen the potential genotypes of tomato giving consistent performance over different locations and to select the genotypes on the basis of stability parameters for important yield and maturity attributes (Kalloo *et al.* 1998).

*Short note

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The quality of the tomato genotypes plays an important role in deciding the suitability of the genotype for processing purpose, fresh market or table purpose. Considering these requirement, quality parameters, viz lycopene content, ascorbic acid, total titratable acidity, *p*H, total soluble solids, per cent juice recovery were estimated in present investigation.

Material for the study was obtained from the Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad. The investigation consisted of 16 advanced breeding lines, viz 'TS 1', 'TS 2', 'TS 3', 'TS 4', 'TS 5', 'TS 6', 'TS 7', 'TS 8', 'TS 9', 'TS 10', 'TS 11', 'TS 13', 'TS 14', 'TS 15', 'TS 16' and 'TS 17' obtained from biparental matings in F_2 generation of commercial F_1 hybrids of 'MHTM 256' and 'S-14-41' along with one check 'L 15' ('Megha'). All the genotypes were evaluated for their stability across 3 locations, viz Botanical Garden of Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad; Main Agriculture Research Station, Saidapur; Water Management Research Centre (WMRC), Belvatagi during winter (*rabi*) season 2008–09. The experiment was laid out in randomized block design with 3 replications. Each entry was represented by 2 rows of 10 plants/replication with row-to-row and plant-to-plant distance of 60 cm. Data were recorded on plant height (cm), number of primary branches, day to 50% flowering, flowers/raceme, number of locules, pericarp thickness (mm), number of fruits, average fruit weight (g) and yield/plant (g). The stability analysis of each of the character was carried out following the model of Eberhart and Russell (1966). In this model a stable variety is being one with a regression slope near to 1, deviation from regression line being close to zero and higher mean yield.

Quality parameters, viz lycopene content, ascorbic acid, total titratable acidity, *p*H, total soluble solids, per cent juice recovery were estimated for all the genotypes. A drop of tomato juice from each reference entry was placed on the prism of Brix hand refractrometer and reading was recorded for total soluble solids estimation. Lycopene content (mg/ 100 g) and ascorbic acid content (mg/100 g) of fruits was

Table 1 Pooled ANOVA for stability of 9 quantitative characters in tomato at 3 different locations

Sources of variation	df	Days to 50% flowering	Plant height (cm)	Pericarp thickness (mm)	No. of locules unit	No. of fruits	Average fruit weight (g)	Yield/plant (g)
Varieties	16	3.95**	1 341.05**	0.525**	1.32**	1 236.31**	199.59**	1 81 073.36*
Environment	2	33.90**	10 118.9**	0.986**	0.218	11 732.03**	35.22	83 41 963.4**
Variety × environment	32	0.77	154.14	0.19	0.117	172.38*	13.45**	1 22 726.63*
Environmental (linear)	1	67.80**	20 238.1**	1.97**	0.437	23 464.08	70.43**	1 66 83 924.0**
Variety × environmental (linear)	16	1.12	261.72**	0.167	0.105	171.49	21.01**	80 146.30
Pooled error	96	1.299	143.07	0.152	0.094	107.01	5.16	71 987.9
Pooled deviation	17	0.403*	43.82	0.207**	0.121**	163.08**	5.54**	1 55 583.14

*P = 0.05; **P = 0.01

estimated through the procedure given by Sadasivam and Manickam (1992).

The pooled analysis of variance (Table 1) revealed that mean sum of squares (MSS) due to genotypes (G) and environments (E) were highly significant for all the characters under study indicating the presence of substantial variation among the genotypes over environments. Significant G×E interaction indicated that genotypes under different environments behaved differently for the expression of characters of interest. It means, a particular genotype may not exhibit the same phenotypic performance under different environments or different genotypes, may respond differently to a specific environment. Pooled ANOVA for stability of the quantitative traits for which data was collected at 3 locations is mentioned in Table 1. The MSS due to environment (linear) was significant for most of the characters indicating that environmental effects are additive. The linear component of G´E interaction was also significant for plant height, number of primary branches and average fruit weight indicating significant rate of linear response of the genotypes to environmental changes for these characters. The pooled deviation was also significant for all the characters except plant height, number of primary branches and yield/plant indicating that non-linear component of G´E interaction was predominant. Similar results were reported by Kalloo *et al*. (1998), Mulge *et al*. (2003) and Aravindakumar *et al.* (2003). Eberhart and Russell (1966) discussed stability of genotypes in terms of 3 parameters namely, genotypic mean (g_i), regression coefficient (b_i) and deviation from the regression (S^2d_i). According to this model, an ideal or most stable genotype is the one having high mean performance, unit regression and no deviation from regression. Environmental indices suggested that for all characters the WMRC, Belvatagi is the best environment and Main Agriculture Research Station, Saidapur is least suited environment except for average fruit weight where opposite situation was observed (Table 2).

More number of fruits/plant was exhibited by the plants grown at WMRC, Belvatagi with environmental index 20.952, while Main Agricultural Research Station, Saidapur with lowest environmental index (–29.472) had less number of fruits/plant (Table 2). Highest mean value for numbers of fruits was recorded by genotype ‘TS 1’ (108.86), while ‘TS 7’ (37.84) had least mean value. Mean value for this trait over all the environments was 75.616. The set of genotypes, viz ‘TS 1’, ‘TS 6’, ‘TS 11’ and ‘TS 17’ were found to be widely adapted to all the 3 locations as concerned with number of fruits as these genotypes had non-significant regression coefficient and deviation from regression coefficient with high mean values. The genotypes ‘TS 5’, ‘TS 8’, ‘TS 10’, ‘TS 13’ and ‘TS 14’ were unstable over all 3 environments, as these genotypes showed significant deviation from regression. The genotypes ‘TS 9’ and ‘TS 16’, with regression coefficient value significantly lesser than unity are indicates their average stability over unfavourable environment. The genotypes ‘TS 2’, ‘TS 3’, ‘TS 4’, ‘TS 7’, ‘L 15’, ‘TS 15’ and ‘TS 16’ had non-significant deviation from regression and high mean indicating more genotype × environment interaction. Aravindakumar *et al.* (2003) also reported high mean value for number of fruits in ‘L 15’ genotype.

The genotype ‘TS 7’ had highest mean value (42.79) for average fruit weight, while ‘TS 1’ had least mean value (21.02). Mean value for this trait over all the environments was 31.607. Saidapur is the most favourable environment

Table 2 Environmental indices of 9 characters in tomato genotypes over 3 different locations

Character	Botanical garden, Dharwad	WMRC, Belvatagi	MARS, Saidapur
Days to 50% flowering	0.334	–1.549	1.215
Plant height (cm)	5.950	20.87	–26.820
Pericarp thickness (mm)	–0.126	0.278	–0.152
No. of locules	–0.094	0.126	–0.032
No. of fruits	8.520	20.952	–29.472
Average fruit weight (g)	–0.695	–0.961	1.656
Yield/plant	268.670	526.71	–795.380

WMRC, Water Management Research Centre; MARS, Main Agriculture Research Station

for average fruit weight as indicated by high environmental index (1.656), where as Belvatagi resulted in less average fruit weight with least environmental index (–0.961). The genotypes, viz 'TS 2', 'TS 7', 'TS 9', 'TS 14' and 'TS 16' had high mean values for average fruit weight with non-significant regression value and non-significant deviation from regression suggesting their adaptability to all the 3 locations for this trait. Similar results were reported by Pandey (1983), Kalloo *et al.* (1998).

The mean values for yield/plant indicated that 'TS 13' was highest yielding (2 608.89), while 'TS 7' was lowest yielding genotype (1 600). Mean value for this trait over all the environments was 2 217.38 (Table 3). As indicated by the environment index (Table 2). AR, Belvatagi it showed highest yield/plant (526.71), while at Saidapur showed lowest yield with low environmental index (–795.38). Rodomiro *et al.* (2007) also reported outstanding marketable fruit yield in high-yielding location but exhibited sharp yield loss in poor environment. The genotypes, viz 'TS 1', 'TS 5', 'TS 6', TS 11, 'TS 15' and 'TS 16' were showed wider adaptability to all the 3 locations as indicated by stability parameters. The genotypes 'TS 3', 'TS 4', 'TS 8', 'TS 10', 'TS 13', 'TS 14' and 'TS 17' were showed significant deviation from the regression coefficient, which indicated the instability of these genotypes over all locations. Remaining genotypes, viz 'TS 2', 'TS 7', 'TS 9' and 'L 15' ('Megha') with low mean values were poorly adapted to all locations. Varied response of tomato genotypes to different environments in case of yield per plant was also observed by Kalloo *et al.* (1998).

The mean values of days to 50% flowering indicated that 'TS 3' required more number of days (29.00), while 'TS 1' recorded less number of days (25.56). Mean value for this trait over all the environments was 27.35 (Table 3). The genotypes 'TS 3', 'TS 4', 'TS 5', 'TS 13', TS 14, 'TS 15' and 'TS 16' showed better adaptability to all the 3 locations for this trait.

The genotype 'TS 1' with mean plant height of 131.29 cm was the tallest and 'TS 3' with mean plant height of 70.98 cm was shortest. The average plant height over the environment was 94.73 cm. The genotypes 'TS 6', 'TS 7', 'TS 8', 'TS 10', TS 11 and 'TS 17' showed better adaptability to all the 3 locations as far as plant height is concerned, as indicated by stability parameters. Since the genotype 'TS 5' exhibited regression value lesser than unity which indicated that this genotype had above average stability for plant height. The line 'TS 1' showed instability over all the 3 locations as it showed significant deviation from regression. Mulge *et al.* (2003) reported stability for plant height and days to 50% flowering in tomato.

The genotypes, viz 'TS 2', 'TS 3', 'TS 4', 'TS 5' and 'TS 14' had high mean values for pericarp thickness with non-significant regression value and non-significant deviation from regression, suggesting that these genotypes

Table 3 Mean performance and stability parameters of tomato genotypes for different morphological traits

Genotype	Number of fruits			Average fruit weight (g)			Yield/plant (g)			Day to 50% flowering			Plant height (cm)			Number of locules			Pericarp thichness (mm)		
	gi	bi	S2di	gi	bi	S2di	gi	bi	S2di	gi	bi	S2di	gi	bi	S2di	gi	bi	S2di	gi	bi	S2di
'TS 1'	108.86	1.40	–33.52	21.02	–1.52	2.00	2 331.11	1.33	–3186.97	25.56	0.36*	–0.43	131.29	2.06	192.9*	2.24	2.05	–0.1	5.12	1.63	–0.01
'TS 2'	60.94	0.567	91.07	35.09	–1.65	4.29	2 126.67	0.91	35540.95	28.44	2.03	–0.41	80.20	0.81	–35.29	2.79	–1.78	0.17*	5.86	2.28	0.00
'TS 3'	66.27	1.04	31.71	30.50	–1.32	4.27	2 044.44	1.34	265244.92**	29.00	.92	–0.28	70.98	0.50	–36.94	2.44	–0.88	0.06	5.99	2.40	0.01
'TS 4'	71.16	1.13	–25.14	28.73	5.52	10.59*	1 905.56	0.62	141480.64*	27.67	1.39	–0.10	77.53	0.62	90.43	2.40	0.47	0.04	5.52	2.02	0.12
'TS 5'	96.43	1.35	348.2**	24.30	–0.57	2.55	2 337.78	1.26	75369.23	28.78	0.72	–0.43	98.96	0.5*	–46.84	2.49	0.26	0.13*	5.51	1.34	0.11
'TS 6'	99.60	1.28	8.93	22.89	1.00	4.16	2 235.56	0.86	–18361.64	26.78	1.11	–0.38	120.13	1.12	–45.71	2.27	2.37	–0.01	4.88	1.71	0.05
'TS 7'	37.84	0.31	7.36	42.79	1.80	–1.56	1 600.00	0.35	57573.32	26.67	1.16	–0.20	99.22	0.78	–35.93	3.36	0.11	0.70*	5.09	2.68	0.52**
'TS 8'	100.46	1.12	192.34*	21.19	–2.26	3.58	2 203.33	1.25	307388.0**	25.89	0.91	–0.08	117.64	1.77	48.11	2.33	–1.00	0.08	5.02	–0.55	0.47**
'TS 9'	51.76	0.71**	–35.67	41.28	1.40	0.13	2 097.78	0.97	–7441.18	27.56	0.92	2.9*	81.67	1.03	–45.96	2.93	2.69	–0.03	5.57	–0.20	0.24**
'TS 10'	87.21	1.37	621.8**	23.97	–0.169	2.46	2 121.11	1.28	742397.00**	25.67	1.00	0.26	116.40	1.15	–45.36	2.32	0.10	0.07	4.67	1.71	–0.01
'TS 11'	101.21	1.69	53.71	24.60	1.50	–1.66	2 426.67	1.29	44058.14	25.78	0.79	–0.21	125.44	1.73	–1.52	2.34	1.92	–0.03	5.33	–0.21	0.29*
'L 15'	73.96	1.05	–35.22	29.43	0.91	3.41	2 137.78	1.00	–5754.26	27.00	0.69	–0.35	75.38	0.46	–42.30	2.74	2.08	–0.03	4.81	1.32	0.02
'TS 13'	65.72	0.90	491.2**	41.63	3.80	20.7**	2 608.89	1.09	166596.73	28.22	1.67	–0.41	73.49	0.64	13.28	3.50	3.67	–.03	5.64	0.28	0.24*
'TS 14'	66.64	0.81	405.5**	39.78	2.08	–0.15	2 607.78	1.05	348192.88	27.78	1.04	0.03	77.31	0.91	–46.30	3.72	–1.24	0.06	5.89	1.67	0.03
'TS 15'	60.57	0.75	–33.37	41.65	4.40	8.26	2 415.56	0.68	–12924.45	28.56	0.98	–0.41	74.64	0.71	2.38	4.48	5.24	0.15*	5.28	0.41	0.32*
'TS 16'	57.38	0.67*	–35.37	40.56	2.76	2.66	2 266.67	0.72	–10335.78	28.33	1.63	–0.11	80.62	0.95	–32.60	3.73	–1.65	0.04	5.12	0.01	0.27*
'TS 17'	79.47	0.85	112.25	27.90	–0.69	–0.87	2 228.89	0.99	111145.36*	27.33	–0.31	0.06	109.60	1.20	1.72	3.32	2.58	0.69**	4.68	–1.51	–0.02
Mean	75.616			31.61			2217.39			27.35			94.74			2.91	5.29				

*P=0.05; **P=0.01

bi, Regression coefficient; S2di, deviation from regression coefficient

Table 4 Different quality parameters for tomato genotypes

Genotype	TSS (°Brix)	Total titrable acidity (%)	Ascobic acid (mg/ 100 g)	Lycopene (mg/ 100 g)	*p*H	Juice recovery (%)
'TS 1'	5.44	0.266	28.64	3.81	4.30	64.54
'TS 2'	5.72	0.270	27.85	7.93	4.29	59.55
'TS 3'	5.82	0.276	29.93	8.11	4.22	72.76
'TS 4'	4.87	0.240	28.46	3.86	4.36	47.57
'TS 5'	5.30	0.280	30.79	5.17	4.20	72.73
'TS 6'	5.59	0.280	29.24	4.62	4.20	72.7
'TS 7'	5.55	0.360	28.99	4.89	3.92	70.19
'TS 8'	5.27	0.330	30.73	5.56	4.09	73.73
'TS 9'	5.71	0.190	28.78	6.13	4.51	63.11
'TS 10'	5.48	0.280	28.46	2.66	4.19	61.71
'TS 11'	5.48	0.276	30.06	6.13	4.28	62.04
'L 15'	5.02	0.350	35.34	4.39	4.02	63.85
'TS 13'	5.41	0.246	23.27	8.56	4.33	63.11
'TS 14'	5.34	0.337	21.99	8.19	4.04	57.82
'TS 15'	5.50	0.337	19.32	9.74	4.08	63.87
'TS 16'	5.32	0.300	30.29	6.72	4.09	56.73
'TS 17'	5.81	0.286	33.65	2.43	4.11	62.73

are well adapted to all the 3 locations for this trait. In case of number of locules the genotypes, viz 'TS 9', 'TS 13', 'TS 14' and 'TS 16' were well stable at all the 3 locations as these genotypes exhibited high mean.

The analysis of quality parameters for all these genotypes revealed their superiority in quality traits compared to check variety 'L 15' ('Megha') (Table 4). The genotype 'TS 15' showed highest lycopene content (9.74 mg/100 g), followed by 'TS 13' (8.56 mg/100 g). 'TS 7' had highest total titrable acidity while 'TS 9' showed least total titrable acidity. Highest ascorbic acid content was observed in 'L 15' genotype. The TSS content which results in high recovery of processing products, was high in 'TS 3', while 'TS 4' showed least TSS content. The genotype 'TS 3' showed highest per cent juice recovery. Genotype 'TS 9' with high pH content (4.51) is suitable for fresh market while genotype 'TS 7' with low *p*H content (3.92) is suitable for processing purpose.

Considering the overall performance the genotypes, 'TS 1', 'TS 6', 'TS 11', 'TS 14', 'TS 15' and 'TS 16' were found to be most stable over all 3 environments for yield-contributing characters. These genotypes can either be used in further breeding programmes or released as promising cultivars for farmers use. The genotype 'TS 1' with high *p*H (4.30) and low titratable acidity (0.26%) showed its suitability for fresh market purpose. While genotypes 'TS 6' and 'TS 11' showed high total soluble solids, ascorbic acid content, *p*H and low total titratable acidity which indicated their suitability for processing as well as fresh market purpose. The genotypes 'TS 14' and 'TS 15' had high lycopene content and total titrable acidity with low *p*H which represented their suitability for processing purpose. High total titratable acidity and low *p*H indicated the suitability of genotype 'TS 16' for processing purpose.

SUMMARY

A study was carried out during winter (*rabi*) season of 2008 for developing new cultivars and in choosing suitable cultivars to grow in specific location on 16 tomato (*Solanum lycopersicum* Mill.) genotypes along with one check across 3 different locations, namely Dharwad, Saidapur and Belvatagi. Genotype × environment interaction was significant for most of the yield related traits suggesting that genotypes interacted significantly with environments. The difference in stability was due to both the linear response of genotypes to environment and deviation from the linear response. None of the genotypes was stable for all the characters and stability for one character was independent of stability for other characters. The genotypes 'TS 1', 'TS 6', 'TS 11', 'TS 14', 'TS 15' and 'TS 16' were found to possess stability for yield related traits. The analysis of quality parameters for all these genotypes revealed their superiority over check cultivar 'L 15' ('Megha').

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